Methyl bromide alternatives

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Inside This Issue

A Successful Structural Fumigation in Canada

During the December 1995 meeting of the parties to the Montreal Protocol, Canada and the United States supported a phaseout of methyl bromide by the year 2001. Some countries, including the Netherlands, Denmark, Norway, and Sweden, will phase out the chemical sooner. In addition, by 1998, Canada, along with other developed countries, will implement a 25-percent reduction in methyl bromide production and use to their respective country's 1991 levels.

One of the primary uses of methyl bromide in Canada is for the fumigation of facilities such as oat and flour mills, warehouses, food-processing plants, and conveyances, such as shipping vessels. Chemical alternatives for structural fumigation in Canada are limited.

"Assessing chemical alternatives for this use is difficult, since it is commonly not only a structure that is fumigated, but also stored food," says Linda Dunn, a senior policy analyst with Agriculture and Agri-Food Canada (AAFC). "We needed to find innovative solutions to this problem, so industry and government teamed up to determine the feasibility of an alternative approach to methyl bromide space fumigation." This approach, developed by David Mueller of the U.S.-based Fumigation Service and Supply Inc., uses a combination of heat, phosphine, and carbon dioxide (CO_2).

AAFC teamed up with Canadian and U.S. pest control industries, the Canadian food-processing industry, Canadian and U.S. suppliers of CO_2 and magnesium phosphide, federal departments of health and environment, and the Ontario Ministry of Environment and Energy to test this alternative to methyl bromide for controlling insect infestations on a commercial scale.

The Quaker Oats Company of Canada, Ltd. donated its mill facility in Peterborough, Ontario for the test. The facility is composed of several joined buildings, parts of which are almost 100 years old, and is typical in some respects of many other Canadian milling and cereal-processing facilities.

"The combination of heat, phosphine, and CO_2 in just the right amounts successfully fumigated the building," Mueller says. Liquid carbon dioxide (vaporized to a gas) was piped in to provide a final average air concentration of 4.3 percent, and magnesium phosphide Fumi-Strips® were distributed on several floors.

This newsletter provides information on research for methyl bromide alternatives from USDA, universities, and industry.

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Phosphine gas levels recorded during the 8- to 36-hour fumigation period ranged from a low of 10 parts per million to a high of 110 parts per million. The time-weighted average concentration was 36 parts per million at 24 hours and 38.2 parts per million at 36 hours.

The temperature of the building was raised to an average of 98.6 °F. The average relative humidity was 18 percent, and the low was 13 percent. Humidity is an important factor when using this type of fumigation. High humidity combined with high concentrations of phosphine may lead to corrosion.

To avoid any potential phosphine damage during the test, areas most likely to corrode were flooded with CO_2 to create small rooms of positive pressure and then sealed with tape. Several polished copper tubes were hung in the fumigated areas as a simple test of corrosiveness. No corrosion damage has been noticed in the facility.

The mill was cleaned and sealed. Quaker Oats employees were responsible for cleaning the facility and equipment during the shift preceding the fumigation. All food-processing equipment was taken apart, blown out, emptied, and cleaned. Equipment and elevator legs were left open to give easy access to the fumigant. Window sills and floors were cleaned of debris and dust, and windows, fire doors, and other entries were taped shut.

From April 12 to 14, 1996, approximately 14 tons of CO_2 were spread through the building using hoses. Initially, six magnesium phosphide Fumi-Strips® were placed on alternating floors. Because of the extremely low humidity within the facility, which led to a very slow release of the magnesium phosphide, 11 additional strips were used during the 36-hour test. The temperature was monitored and maintained at 86 to 104 °F.

The final preparation before fumigation involved the placement of pests. Adults, larvae, and eggs were placed in several locations by three different experimenters. In one test, conducted by Colin Demianyk of AAFC's Cereal Research Centre, in Winnipeg, pairs of vials of confused flour beetles (*Tribolium confusum*), each containing either 10 adults or 10 eggs, were placed in 10 locations on each floor. Demianyk notes, "The locations were chosen because they either seemed to be cool areas by windows or doors, or were potentially more difficult for the fumigant to reach, for instance, behind equipment."

Control vials of test insects were exposed to a maximum temperature monitored at 82 °F for several hours during setup. Controls were then kept at ambient humidity and 68 °F throughout the test.

After fumigation, control insects were brought back to the test building during the collection of the test insects, and then transported in hand luggage back to the Cereal Research Centre in Winnipeg. All insects, test and control, were incubated at 86 °F and 70 percent relative humidity within 30 hours after the completion of the test.

Adult pests were examined the next day for survival. They were then placed with vials of eggs to incubate for 30 days to determine if any eggs laid by adults during fumigation survived. No adults survived in a 900-insect sample.

"We learned a lot from this fumigation test," comments Bernie McCarthy of PCO Services Inc. (an S.C. Johnson Wax Company), project manager for the test. "The experience pointed out the importance of constant monitoring and adjustments to maintain the correct balance of heat, phosphine, carbon dioxide, time, and relative humidity."

Demianyk points out that a combined heat/carbon dioxide/ phosphine treatment killed more than 98 percent of confused flour beetle eggs and 100 percent of adults.

Under traditional methyl bromide fumigations, a 95-percent kill rate is considered successful. The combination fumigation method used at the Quaker Oats mill in Canada exceeded this rate, even under adverse conditions that included low ambient humidity, several leaks, and cold external temperatures.

"We believe that this commercially viable alternative fumigation method to methyl bromide in large facilities has the potential for extensive use in Canada's food industry," Dunn concludes.

U.S. Perspective

The treatment combining heat, phosphine, and carbon dioxide used earlier was first tested in 1993 at Purdue University on an experimental mill. To date, 38 fumigation treatments (24 on flour mills) have been successfully performed in the United States.

High humidity and high concentration levels can cause corrosion when fumigating with phosphine, but high humidity can be controlled by piping large volumes of carbon dioxide into the buildings. "This normally reduces relative humidity by about 10 percent," says Mueller. There are

methods being researched to better manage humidity and corrosion.

Successful fumigations have been conducted in large (3,800,000 cubic feet), modern, computerized food-processing plants with no startup or corrosion problems. The tests have worked even with the relative humidity above 70 percent and extended periods of rain.

Mueller notes, "This approach is 25 to 40 percent more expensive. Although it is not a total answer to the methyl bromide problem, tests show it can be a successful alternative in flour mills and food-processing plants."

The Netherlands' Alternatives to Methyl Bromide

"Fifteen years ago, the Netherlands was one of Europe's major users of methyl bromide for soil fumigation," says Joop A. Van Haasteren. "But we no longer use it. In 1967, mechanically injecting methyl bromide in greenhouse soil became controversial. Consequently, our government imposed more stringent requirements on the use of this and other fumigants, and eliminated the use of methyl bromide for soil fumigation in 1991."

However, methyl bromide is still used in the Netherlands to fumigate stored products, structures, furniture, and as a quarantine treatment, according to Van Haasteren. He is with the Netherlands Ministry of Housing, Planning, and Environment.

Prior to the phaseout, Dutch growers used about 3,000 tons of methyl bromide annually to control soilborne pests on greenhouse-grown crops such as tomatoes, lettuce, strawberries, cucumbers, sweet peppers, as well as nursery crops and cut flowers. However, only small amounts were used to fumigate soil for field crops.

Instead, growers in the Netherlands now use soil-less mixtures of artificial and natural-growth compounds, steam sterilization, and chemical and nonchemical alternatives.

"We also rely on crop rotation," Van Haasteren explains. "And, we've had good results with chemical substitutes such as metam sodium, dazomet, and 1, 3-dichloropropene."

During the phaseout period between 1980 and 1991, Dutch growers maintained, and actually increased, production of horticultural crops that were once dependent on methyl bromide.

Successful crop production without methyl bromide in the Netherlands has been achieved "through research, adequate supplies of good-quality water, and available energy," Van Haasteren says. "Just as important has been our growers' ready access to high-priced product markets and their good management and technical skills."

In the Netherlands, about 8,000 growers produce 70 percent of the world's cut flower exports and 51 percent of world plant exports. Also, more than 3,500 nurseries produce 25 percent of the world's tree nursery stock, which includes pot- and container-grown plants, forest trees and shrubs, avenue and park trees, perennials, ornamentals, fruit trees and fruit tree rootstock, and rose culture and rootstock.

To wean themselves from methyl bromide, in the first step of the 10-year phaseout, Dutch growers reduced the amount of the fumigant needed by improving the method of application. They used sheets of gas-tight plastic to cover the soil in greenhouses, thereby decreasing the amount that escaped into the air and cutting the quantity needed.

In most cases, soil replacements such as rockwool, rock, clay and pumice granules, flexible polyurethane foam blocks, and coconut fibers are all being used as basic methods to replace methyl bromide for growing flowers, tomatoes, strawberries, cucumbers, peppers, and eggplants. With these soil replacements, there is no longer a danger of infestation by soilborne pests.

"Our growers report, on average, a 10- to 20-percent increase in cash income with these artificial substrates," Van Haasteren says. "We're primarily using biological controls for pests that don't require soil. But, control of secondary fungal or bacterial diseases that occur during the growing period may be necessary."

For growing strawberries without soil in greenhouses, the Netherlands developed a system of hanging the plants, which grow in peat blocks, to prevent contact with any soilborne diseases. Nutrient-enriched water is pumped to the plants, reducing plant wetness and related foliage pest problems. The wastewater from the roots is recaptured, sterilized, and reused.

"After investing in this system, growers significantly increase production and can harvest up to three crops each year," according to Van Haasteren.

In the Netherlands, a wide range of soilborne pests can be killed by sterilizing the soil with steam. Using natural gas to heat water, Dutch

growers treat soil in greenhouses with steam. The high cost of energy and the inability of steam to penetrate deeply into the soil are limiting factors with this alternative to methyl bromide. In the Netherlands, however, industrial customers get volume discount prices. Permeable soil beds use anywhere from 2.5 to 5 cubic meters of natural gas per square meter of greenhouse area per year; less permeable soils can require as much as 8 cubic meters. Steam sterilization cannot be used in low permeable soils or those with a high peat content or a high soil-water table.

Van Haasteren says that the Netherlands has developed a way of surface-injecting steam under plastic sheets, then using negative pressure ventilation to draw the steam into ducts buried 50-70 cm below the soil surface, thus reducing the energy input. Of course, this requires a capital investment in a permanent duct/drain system under the greenhouse.

An economic advantage of steam sterilization in the Netherlands is that growers can replant immediately after the soil cools, in less than 5 days. With methyl bromide, growers had to wait 3 weeks.

Although growers are using metam sodium, dazomet, and 1, 3-dichloropropene, these chemical substitutes are less effective than methyl bromide and often less suitable for some crops and pests. The soil can adapt, pests become resistant to the pesticides, and some chemicals require long waiting periods for planting.

"Since a major economic part of our agriculture is produced in greenhouses, the alternative practices we've discussed were implemented fairly easily by our growers," Van Haasteren says. "We have many small farmers close to residential areas and our climate is cool, with limited sunlight. The increased product quality, easy access to domestic and world markets, high food and flower prices, and skilled growers were all to our advantage."

Dense concentration of independent growers in a small area allows them to share contracted services such as a good infrastructure for getting substrates, pest control advisors, and mobile sterilization equipment for plant beds.

"Although we have found no single alternative to methyl bromide, growing crops with soil-less substrates has proven to be very successful," Van Haasteren concludes.

Use of Alternatives in the Netherlands: A Florida Perspective

Even without the aid of methyl bromide, growers in the Netherlands continue to be major producers of winter vegetables for the European Community, and generally command high market prices.

"European consumers pay a much higher price for agricultural commodities than we pay here in the United States," says Joseph Noling. He is an extension nematologist with the University of Florida's Institute of Food and Agricultural Sciences at Lake Alfred, FL. "Compared to the United States, they also spend a much higher proportion of their income on food, for serving portions that are typically smaller than ours."

Food pricing, capital investment, and environmental considerations prohibit U.S. growers from adopting the methyl bromide alternatives that seem to be so successful in the Netherlands, Noling says.

Food Pricing and Competitive Markets

U.S. growers provide high-quality, inexpensive, ample supplies of fruit and vegetables year round.

"Access to high-priced product markets has allowed Dutch growers to adopt high-cost, energy-dependent alternatives to methyl bromide, such as steam," Noling says. "But, growers in Florida face quite a different situation."

For example, Florida tomato growers must compete with Mexican growers. Currently, Mexico enjoys reduced labor costs, one-tenth those of the United States, while we have the advantage of lower transportation/shipping costs, as well as 60 percent higher productivity per unit of land.

But changes are looming on the horizon that will affect this "balance" of competitive advantage. In the year 2000, Mexico will ship directly to U.S. markets without tariffs, off-loading fees, or middleman brokerage fees. Mexico is investing heavily in new technology. And, if Mexican growers continue to expand their use of methyl bromide, they will further close the gap by cutting production costs and increasing yields.

"As an example of the current competition with Mexico, 75 percent of Florida growers are claiming 40 percent or more loss for their 1996 spring tomato crop," Noling reports. "Also, we have an alarming number of farmers who are declaring bankruptcy, downsizing their operations, or cutting back on acreage planted in tomatoes."

In the future when methyl bromide is no longer available, those U.S. growers who are still in business will be forced to use a combination of replacements, facing almost certain increases in production costs and possible reductions in crop yields.

In the short term, U.S. researchers have focused on developing alternative pest and crop management strategies that will consistently give growers returns that are equivalent to what they now get with methyl bromide.

Noling says that "almost by necessity, this has placed the emphasis on studying chemical alternatives such as 1,3-D and chloropicrin (Telone C-17), combined with a herbicide."

U.S. growers recognize that they will not be able to rely exclusively on chemicals for future pest management. For some time now, researchers have been investigating and evaluating individual strategies and combinations of strategies, such as changes in cultural practices, crop rotation, soil amendments, solarization, and resistant plant varieties. While many of these show promise for certain pests or specific pest complexes, Noling says they don't have the wide-range effectiveness of methyl bromide.

Therefore, the challenge remains to find a more sustainable, integrated pest management approach. This, as we are all well aware, will take time, continued field research, and an interdisciplinary, cooperative effort between agricultural scientists and the farming community.

Capital Investment

Unlike the Netherlands, most U.S. crop production occurs in the field. And, it would not be economically feasible to convert U.S. field production to greenhouse technology.

"In addition to the initial outlay of millions of dollars for construction of greenhouses, the cost for a system to generate steam, in this country, would be extremely high," Noling says. "This is not counting the permanent duct/drainage systems needed for greenhouse production."

Assuming diesel cost at only $1 per gallon, fuel consumption to generate steam could well range up to about $1,000 per acre, according to Noling. Also, U.S. growers can't depend on a long-term diesel supply, and they don't have ready access to natural gas.

Environmental Considerations

It has been reported that burning fossil fuels adds significant amounts of carbon dioxide to the environment. If U.S. growers converted to greenhouse production, one of the potential major problems would be higher carbon dioxide emissions from diesel fuel.

"This could intensify global warming, which may become a problem similar in magnitude to that of the ozone depletion caused by methyl bromide," Noling notes.

Florida growers are blessed with a warm, wet, humid subtropical climate. Unfortunately, this is a mixed blessing, since it is also an excellent environment for myriad soilborne and foliar pests and plant pathogens.

"Because of these climatic differences, our pest problems appear to be much more diverse, intense, and volatile than in the Netherlands where it's usually cool with little sunlight. Also, the high water tables in Florida make it very difficult to treat pests with steam because of the tremendous temperature-buffering capacity of the soil," Noling says.

Florida soils are sandy, favoring weeds and pests like the root-knot nematode (*Meloidogyne* spp.). And because of Florida's mild winters, these weeds and pests can reproduce and grow year-round.

Technical Reports

Research on Alternatives to Methyl Bromide for Control of Soilborne Pests of Grapevines and Tree Fruits and Nuts

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Methyl bromide is widely used in California as an effective preplant fumigant to control soilborne pests that affect deciduous tree fruits and nuts and grapevines. Depending on the particular commodity, orchard and vineyard lifetimes typically exceed 1–5 or more decades, and the establishment costs are relatively high. Therefore, sustained and profitable production of these crops requires prudent preplant preparations and postplant pest management strategies.

The pests of concern include a broad range of weeds, nematodes, insects, and fungi. Many of the pests and their effects and biology are well documented. For example, several species of plant parasitic nematodes and pathogenic soilborne fungi are commonly encountered in California agriculture, especially when orchards or vineyards are replanted at old sites previously devoted to the crops. These pests can severely debilitate and, in many cases, kill trees and vines. Most investigators believe that additional factors or pests (sometimes referred to as the "replant problem"), although not well documented or understood, operate at "replant" sites and reduce vigor and productivity of the perennial crops unless preplant precautions, such as methyl bromide fumigation, are taken.

At USDA–ARS and University of California (UC), Davis, scientists are working cooperatively and independently on development of alternatives to preplant fumigation with methyl bromide. Both chemical and nonchemical alternatives are under investigation, and the target problems include well-documented "acute" pests, as well as the more "chronic" and poorly understood general replant phenomenon.

Work led by Dr. Greg Browne, research plant pathologist with USDA–ARS, Davis, emphasizes genetic and cultural alternatives to methyl bromide for control of Phytophthora root and crown rots of deciduous trees and vines. With walnuts, Browne is evaluating promising clones of paradox (*J. hindsii* × *J. regia*) rootstock as well as selections and hybrids of Chinese wingnut that offer hope for superior resistance to *Phytophthora* spp. The evaluations are the next step in testing "elite" paradox rootstock clones that were preserved from previous screens for resistance to *Phytophthora* spp. led by ARS research plant pathologist Dr. John Mircetich (retired). UC pomologist and walnut breeder, Dr. Gale McGranahan, has backcrossed selections of paradox with English walnut to obtain tolerance to cherry leafroll virus, and Browne's group will determine relative resistance of these paradox backcross clones to *Phytophthora* spp.

While a student with Mircetich, Dr. Michael Matheron determined that Chinese wingnut is highly resistant to the most damaging *Phytophthora* spp. that affect walnuts in California. Because the wingnut selections evaluated are graft compatible with only some commercial English walnut varieties, additional research is needed to determine if broad graft compatibility can be combined with the resistance to *Phytophthora* spp. in an improved wingnut rootstock. To this end, Browne's team is screening additional wingnut selections and attempting hybridization of wingnut with English walnut. Improved genetic resistance to *Phytophthora* spp. is also needed in rootstocks for commercial *Prunus* spp. and grapevines. Phytophthora root and crown rots sporadically cause devastating losses in almond and peach plantings. Due to *Phylloxera*, the grape industry is shifting toward use of rootstocks, some of which may be relatively susceptible to *Phytophthora* diseases despite their resistance to the root aphid. In collaboration with plant geneticists, Dr. Craig Ledbetter, research horticulturist, USDA–ARS, Fresno, and Dr. Andrew Walker, professor of viticulture, UC Davis, Browne's group is seeking improved resistance to *Phytophthora* spp. in germplasm of *Prunus* and *Vitis*.

To evaluate a cultural alternative to methyl bromide for control of *Phytophthora* root rot of walnuts, Browne is cooperating with Dr. Robert Hutmacher, research plant physiologist, USDA–ARS, Fresno, to test microsprinkler water management strategies in a commercial orchard setting. For control of southern blight in apples, UC Farm Advisor Joseph Grant and Browne are evaluating chemicals and the biocontrol agent *Gliocladium virens* GL-21 (SoilGard™) as alternatives to methyl bromide + chloropicrin. In year one of the experiment, metam sodium

performed as well as the methyl bromide/chloropicrin mixture for control of the disease at tree replant sites.

Browne is also seeking a better understanding of general replant problems that do not necessarily kill plants but do suppress general vigor and productivity of young trees and vines. In cooperation with J.M. Duniway, professor of plant pathology, UC Davis, Browne will determine the role of fungal and bacterial components of the rhizosphere soil microflora in replant problems with grapevines and deciduous fruit and nut trees. Browne and Duniway will determine if important effects of preplant fallowing, soil amendments, and chemical treatments may be mediated through rhizosphere microflora.

Dr. Becky Westerdahl, extension nematologist, UC Davis, is continuing evaluation of sodium tetrathiocarbonate (STTC, trade name Enzone), which is a candidate alternative to methyl bromide for control of plant parasitic nematodes in deciduous tree crops. STTC, which releases carbon disulfide in soil, offers potential as a postplant as well as a preplant treatment. To date, pre- and postplant STTC treatments have reduced populations of ring, root knot, and lesion nematodes on selected crops. In cooperative research supported in part by USDA–ARS, Westerdahl will determine efficacy of alternative hot water treatment strategies for eradication of nematodes on deciduous tree nursery stock. The cooperative support will also foster Westerdahl's continuing evaluations of chemical alternatives to methyl bromide for preplant nematode control, including STTC, formulations of a nematicidal fungal toxin from Abbott Laboratories, and ozone.

In another project on alternatives to methyl bromide for tree crops, USDA–ARS is working cooperatively with Dr. Dave Rizzo, assistant professor of plant pathology, UC Davis. Rizzo is studying the biology and control of Armillaria root rot (oak root fungus disease) in California. In the cooperative research, Rizzo is evaluating pre- and postplant Enzone treatments as an alternative to methyl bromide for control of Armillaria in pears. Other lines of investigation include the effects of soil-water management on disease expression; this includes a comparison of flood- and sprinkler-irrigated orchards.

Alternatives to Methyl Bromide for Eradicating Pests in Exported Softwood Chips, Lumber, and Logs

L. David Dwinell, Research Plant Pathologist, Southern Research Station, USDA Forest Service, Athens, GA 30602.

Global transport of wood fiber without causing environmental harm or ecological disaster requires that the wood be free of pests. USDA Forest Service research on decontaminating coniferous chips, green lumber, and logs has concentrated on the pinewood nematode (PWN) *Bursaphelenchus xylophilus* and its pine sawyer (*Monochamus*) vectors. Methyl bromide has been the treatment for this and other quarantine pests of logs and other wood products. Mitigation procedures that have been investigated over the past decade include fumigation, irradiation, chemical dips, and elevated temperature.

A native of North America, the PWN has become a destructive introduced pest in the forests of Japan and other Asian countries. *Bursaphelenchus xylophilus*, carried by pine sawyers, are transmitted to recently felled logs or dead or dying conifers, particularly pines, during oviposition. These pests may be found in chips, green lumber, and logs. The PWN has been intercepted in chips, green lumber and packing-case wood exported from North America. As a result of these and other interceptions, the European Union and other countries regulate all coniferous imports to protect their forests from the PWN and other exotic pests.

USDA scientists from the Southern Research Station of the Forest Service and the former Stored Products Insects Research and Development Laboratory of the Agricultural Research Service determined that metam sodium and aluminum phosphide were effective in eradicating the PWN in southern pine chips. To demonstrate the practicality of in-transit fumigation, they applied phosphine to a shipload of woodchips exported from Georgia to Sweden. The experiment was successful and awaits broader application.

The irradiation of pine chips was considered to be an alternative to fumigation. Southern Research Station and Georgia Institute of Technology scientists treated PWN-infested wood samples in a cesium-137 irradiator and found 0.9 MRAD to be the lethal dosage. Subsequently, Canadian scientists reported that 0.7 MRAD dosage (cobalt 60 gammacell 220 irradiator) will eliminate the PWN in aqueous solution. These data support the contention that a higher dosage is necessary to eliminate the PWN *in vivo* than *in vitro*. The scientists concluded that 0.9 MRAD was too high to make this an attractive

means of disinfestation for commercial wood.

The Southern Research Station studied the efficacy of dip-diffusion sodium borate treatments for eradicating the PWN in chips and for eradicating the PWN and pine sawyers in debarked pine logs. Neither the liquid nor the powder formulations were effective in controlling PWN or pine sawyers. However, in a companion treatment, PWN and sawyers were not recovered from pine logs fumigated with methyl bromide at the rate of $240g/m^3$.

Using elevated temperatures to eradicate mesophilic organisms in wood shows the most promise. Mortality of the PWN and its vectors in wood is primarily a function of moisture content, heat source, time, and temperature. For example, conventional heat, live steam, and hot water can raise wood temperatures to levels that are lethal to the PWN (greater than 45 °C). Research by scientists from Georgia Institute of Technology and the Southern Research Station determined that the mortality of the PWN in pine chips exposed to radio frequency waves was a function of temperature. In a subsequent study, they evaluated the effectiveness of radio waves and steam, alone or in combination, on PWN-infested chips. High temperatures are possible in less time by combining steam and radio waves, suggesting that the relationship between these two heat sources may be synergistic. Cooperative research between Southern Research Station and Canadian scientists found that a radio-frequency/vacuum kiln was effective in eliminating the PWN and its vectors in sawn wood.

Elevated temperature can pasteurize or sterilize softwood chips, sawn wood, or logs. Heating southern pine chips, green lumber, and logs to a corewood temperature of 60 °C for 30 minutes is sufficient to eliminate such mesophilic pests as PWN, pine sawyers, and pathogenic fungi. A team of scientists from the Southern Research Station, European Union, and Canada concluded that heating coniferous wood to a corewood temperature of 56 °C for 30 minutes will eradicate the PWN and its vectors. Shorter exposure times can be achieved with thermal treatments, such as live steam and radio waves, that rapidly heat the wood to high temperatures.

Drying coniferous wood at conventional kiln schedules is essentially a wood sterilization process. The time-temperature schedules required to dry sawn wood to commercial standards are much higher than those required to eradicate pests in the wood. This has been confirmed by Southern Research Station, Finnish, Canadian, and South Korean scientists.

Europe now accepts coniferous chips, sawn wood, and logs that are certified to have been kiln-dried or treated at 56 °C for 30 minutes. South Korea now allows the importation of kiln-dried pine sawn wood. The research and development on elevated temperature as a mitigation procedure for decontaminating transported wood has required the cooperative efforts of several countries. Many individuals within the USDA Forest Service, Foreign Agricultural Service, Agricultural Research Service, and Animal and Plant Health Inspection Service worked together to bring science and politics together. The value of these wood exports to the United States has been estimated at $355 million per year.

Similar control principles are appropriate for export or import of chips, green lumber, or logs. Pest control begins in the forest, but forest practices should be followed by heat or other mitigation procedures in the ideal wood management system.

Effect of Soil Solarization and Cover Crops on Populations of Selected Soilborne Pests and Plant Pathogens

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The nursery industry has a major economic impact in the Pacific Northwest, with annual revenues in excess of $400 million. Soilborne pathogens and pests cause substantial losses in many perennial, herbaceous, and woody nursery crops in the region. Hundreds of thousands of dollars of nursery crops are estimated to be lost on an annual basis due to *Phytophthora* species. *Verticillium dahliae* is also an important pathogen, particularly on maple. Crown gall, caused by pathogenic *Agrobacterium* species, is an important disease with estimated annual losses as high as $400,000. Interstate movement of nursery stock infected with plant parasitic nematodes such as *Pratylenchus penetrans* may be restricted, causing an economic loss to nurseries. With the impending loss of many chemicals such as methyl bromide, greater losses from these pathogens may be expected.

During the last 2 years, soil solarization has been evaluated alone and in combination with cover

cropping or applications of metam sodium as alternatives to methyl bromide for controlling these pathogens. Replicated field plots were established in a silty clay loam soil near Corvallis, OR. The main treatments were solarized and nonsolarized plots and subplots consisted of (a) green manures from cover crop, (b) application of metam sodium, (c) clean fallow plots, and (d) noninoculated control plots.

Peppermint plants infested with *P. penetrans* were planted in the plots in April 1994 to establish nematode populations. On May 22, 1995, *V. dahliae* and *P. cinnamomi* inocula were broadcast on the soil surface and the plots were rotovated to a depth of 20 cm. The cover crops, 'Trudan 8' sudangrass, 'Mica' barley, and 'Dwarf Essex' rape, were planted in one-half of the plots. The remaining plots were maintained as clean fallow controls or treated with metam sodium. On July 22, the cover crops were chopped, a suspension of *A. tumefaciens* was sprayed on the soil surface, annual bluegrass seed dispersed on the plots and they were rotovated to 20 cm. Plots were then irrigated to thoroughly wet the soil. Metam sodium plots were sprayed with 235 or 935 L ha-1 (the recommended rate), rotovated to 20 cm, and rolled to seal the soil surface. Finally, a 0.6-mil plastic film was then stretched over solarized plots. The plots were solarized for 2 months from July 22 to September 19. Soil temperatures were monitored in solarized and nonsolarized soils at 5, 10, and 20 cm. The summer of 1995 was slightly cooler than normal. However , the mean and maximum daily soil temperatures in solarized plots at all depths were 30 to 38 °C and 40 to 50 °C, respectively, 8 to 10 °C higher than nonsolarized soil.

To assay population densities of the pathogens, soil samples were collected in May when cover crops were planted, in July at the start of solarization, 1 month later in August, and when the tarps were removed in September. In addition, nylon bags containing soil inoculated with *V. dahliae* and *P. cinnamomi* were buried in each plot at depths of 5, 10, and 20 cm in July. Pathogen population densities in the soil bags were assayed in August and September. The effect of treatments on weed populations was evaluated by quantifying the emergence of seedlings in the plots and in plot soil potted in the greenhouse. In general, soil solarization greatly reduced the population densities of *V. dahliae*, *P. cinnamomi*, *A. tumefaciens*, and *P. penetrans*. However, solarization, cover cropping, and cover cropping followed by solarization were not as effective as metam sodium at the recommended rate. Population densities of the pathogens were not significantly different in soil collected after 30 or 60 days of solarization. The effective depth of solarization was dependent on the pathogen. *P. cinnamomi* was rarely recovered in soil buried at 20 cm in solarization-cover crop treatments, but *V. dahliae* inoculum was not significantly reduced at this depth. The emergence of annual bluegrass and other weeds was significantly reduced in solarized soil. In June 1996, susceptible woody host plants were planted in the plots. These plants will be evaluated for disease incidence and severity for 1 year.

Depending on the organism, cover cropping was neutral in effect or actually increased pathogen populations. Since agrobacteria survive better on plant material, the cover crops may have enhanced the survival of agrobacteria in nonsolarized soil and gave no added benefit to solarization. Solarization and cover cropping did not reduce population counts of fluorescent pseudomonads, spore-forming bacteria, and *Actinomycetes*, all potentially beneficial microorganisms. Our results indicate that soil solarization has the potential for nonchemical management of important soilborne pathogens in this region of the U.S. Over the next year we will determine how solarization and its impact on the pathogen populations relate to disease expression in selected perennial hosts. Further investigations are needed to determine the conditions in which solarization may be an effective and practical method for control of soilborne diseases of perennial plants.

EPA Grants Funds for Potential Methyl Bromide Alternatives

It hasn't been given much publicity, except by word of mouth. But the word seems to be getting around about a fairly new grant program at the U.S. Environmental Protection Agency (EPA). Although not part of any formal program by any means, the fund is administered by EPA's Stratospheric Protection Division and would be used for overhead expenses were it not being allocated to test replacements for methyl bromide.

"Our first grants were awarded to strawberry and tomato growers. We selected these growers because we knew that methyl bromide is used extensively on these two crops," says William B. Thomas. Head of the methyl bromide program at EPA, Thomas has awarded about $550,000 since 1993 to growers and others

seeking replacements for methyl bromide. It's too early yet to evaluate the success of any of the projects, he says.

"Overall, we distribute about $150,000 each year, with an average grant of about $25,000–$40,000," Thomas explains. "We started the program after hearing growers say that they felt powerless in the search for something to replace methyl bromide. At that time, growers were concerned about availability of information on what alternatives might be out there and what research was actually being done to test them."

The EPA doesn't tell growers how to use the money, Thomas says, but it does ask for feedback on results. The only criteria that must be met to be eligible for grant funds is that the organization be nonprofit. No funds are allocated to commercial companies. Studies funded so far include chemical as well as nonchemical alternatives to methyl bromide.

"We're not trying to compete with USDA's research grant program, nor are we funding any kind of basic research on methyl bromide alternatives," he says. "We're just trying to help out those growers who might not otherwise be able to try an alternative to this chemical they have relied on for so long."

Some of the projects funded through EPA include:

- sponsoring grower-defined investigations of potential alternatives for strawberry production at the farm level in California in collaboration with the California Strawberry Commission.
- helping the Florida Fruit & Vegetable Research and Education Foundation evaluate alternatives to methyl bromide for growing tomatoes in plastic mulch, and helping University of Florida scientists study potential alternatives for tomato growers.
- supporting a survey by the Washington State Tree Fruit Association to define and implement nonchemical treatments for postharvest cherries.
- funding an investigation of soil solarization in southern California nursery production by the University of California at Riverside.
- supporting an Oregon State University study of possible methyl bromide alternatives for forest tree nurseries.

Thomas says that EPA has also helped fund the annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction since the conferences first began in 1994.

To apply for a grant, simply send a two-page summary of the proposed project—along with a preliminary budget—to William B. Thomas, U.S. Environmental Protection Agency, Office of Atmospheric Programs, Mail Code 6205J, 401 M Street, SW, Washington, DC 20460; Fax, (202) 233–9637, voice, (202) 233–9179; e-mail, thomas.bill@epamail.epa.gov.

"One way of protecting the environment is to help find alternatives to methyl bromide," Thomas says.

Request for Proposals

United States–Israel Science and Technology Foundation

The U.S.-Israel Science and Technology Foundation is seeking research proposals on methyl bromide alternatives to fund under its joint partnership that includes U.S. and Israeli companies and academic as well as private research institutions. Funds are available for research and development of methyl bromide alternatives, emissions reduction, improved ways to apply the chemical, and ways to contain emissions.

Proposals must be U.S.-Israeli joint ventures, with one partner based in the United States and one in Israel. To receive funding, the U.S.-based partner, or each member of a consortia, must be incorporated in, and have its principal office in, the United States. Likewise, the Israeli-based partner must be incorporated in Israel and maintain primary offices there.

Through the foundation, the United States and Israel are each offering $600,000 for research that will significantly benefit both countries in their quest to find alternatives to replace methyl bromide, reduce or contain emissions, and improve application of the fumigant.

Funds awarded by the foundation must be matched by at least an equal amount by parties to each U.S.-Israeli joint venture. In the case of multiple firms, the aggregate of funds from partners of both countries must at least equal funds granted by the foundation.

Project Eligibility

To be eligible for funding, research must address a potential alternative to methyl bromide or cover containment technology in some way. Areas covered include emissions reduction; soil and quarantine fumigation; soil, water, and nutrient management; plastic containment; and effective dosage.

Projects must include technical innovation or improvement, significant commercial potential, and economic benefit to both the United States and Israel. In fact, applicants must define a plan to commercialize the research within 48 months from the beginning of the project.

Application Requirements

Single proposals must not exceed 40 pages; joint proposals, 50. Submit proposals with a type font no smaller than 12 point, on regular $8\frac{1}{2} \times 11$ inch paper, with no fold-out inserts. A one-paragraph summary of the project—that maintains the confidentiality of the research—is required.

Applicants should include a business plan with their proposal which must contain the following:

- executive summary (3 pages maximum)
- description of project and technology involved
- objectives for commercialization including economic benefits to U.S. and Israel
- commercialization plan, including project objectives, target markets and strategy, technology transfer application and intellectual property and additional capital requirements
- description of project participants' qualifications and time schedule
- detailed project management, including organizational structure, equipment, facilities, and support
- proposed budget.

Where To Apply

Applicants should prepare five copies of their proposals and submit them as follows:

USISTC, Technology Administration
Department of Commerce, Rm. 4821
1401 Constitution Avenue, NW
Washington, DC 20230 (2 copies)

USISTC, Ministry of Industry and Trade
1 Ben Yehuda Street
Migdalor Building
Tel Aviv, Israel 63801 (2 copies)

U.S.-Israel Science and Technology Foundation
c/o Ohad Marani, Embassy of Israel
3514 International Drive, NW
Washington, DC 20008 (1 copy)

Applications must be received by December 31, 1996. The foundation expects to select projects for funding by mid-February 1997. If selected, research projects will be funded for 4 years. No indirect costs are covered.

Evaluation Criteria

The foundation will evaluate research proposals based on the following criteria:

1. Scientific and Technical Merit (30 percent)
2. Commercial Benefits (20 percent)
3. Commercialization Plans (20 percent)
4. Qualification of the Proposing Organization (15 percent)
5. Applicant's Level of Commitment and Organization Structure (15 percent).

For Additional Information

There is additional information on applicant certification, evaluation criteria, rights of the U.S. and Israeli Governments, and other requirements. For a complete copy of the Request for Proposals, contact Lee Bailey, Executive Director, U.S.-Israel Science and Technology Commission, 1401 Constitution Avenue, NW, Washington, DC 20230, Phone (202) 482–6351, or access the USDA–ARS methyl bromide research homepage at **http://www.ars.usda.gov/is/mb/mebrweb.htm**.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.
